

# THE FIRST TWO-WAY TIME TRANSFER LINK BETWEEN ASIA AND EUROPE

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## Abstract

*By establishing the TL (Taiwan)-VSL (the Netherlands) link, the feasibility of using Two-Way Satellite Time and Frequency Transfer (TWSTFT) method for routine comparison between Asia and Europe has been demonstrated. This experiment has been undertaken, once or twice per week, over a period of more than 8 months. Although the elevation from VSL was only 4.9 degrees, the performance of this link is still good. The RMS value of the difference between TWSTFT and GPS Common-View (GPS CV) results is about 3.1 ns. The development, results, and conclusions about this link are illustrated in this paper.*

## INTRODUCTION

Two-Way Satellite Time and Frequency Transfer (TWSTFT), other than the GPS common-view method, has currently become one of the major time transfer techniques because of its high precision that can be achieved. The time transfer data obtained from the regular experiments in Europe and North America have been used to calculate the international atomic time (TAI) since 1998 [1].

The development of TWSTFT in Asia-Pacific Rim region is very active recently and the TWSTFT networks are organized by five laboratories, including the Communications Research Laboratory (CRL) in Japan, the National Time Service Center (NTSC) in China, the National Measurement Laboratory (NML) in Australia, the National Metrology Institute of Japan (NMIJ), and Telecommunication Laboratories (TL) in Taiwan [2]. Three links, which are CRL/NMIJ, CRL/NTSC and CRL/TL, have been introduced into the computation of TAI since January 2002 [3]. However, the only time transfer link between Europe and Asia is the PTB-CRL GPS CV single channel [4] currently. A real Asia-Europe TWSTFT link would be very helpful to enhance the time transfer reliability and be beneficial to the TAI contributions from the APMP region.

The topic of establishing an Asia-Europe link was first discussed in the 9th TWSTFT meeting of the CCTF WG [5]. Both TL and VSL are interested in setting up this link. After several satellites were surveyed, the PAS-4 satellite at 72°E was found to be suitable for the TL-VSL link, i.e., a straight duplex connection between VSL and TL is possible with the present interconnections of the PAS-4 transponders

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and antennas.

However, a practical problem for this link is that the polarizations with PAS-4 were different from what were normally used in the VSL-USA link. VSL has to adjust their earth station, which is presently used for the regular USA link, for setting the TL-VSL link. The polarization adjustment is a difficult manual operation for VSL. Besides, their software also has been adapted to enable it to operate in manual mode and to follow the instructions given by the PAS Network Operations Center.

In order to establish the TL-VSL link, TL set up an individual Ku-band earth station in March 2002. VSL was also devoted to this plan and was willing to adjust their earth station by re-pointing the antenna and rotating the polarization for the pre-test. The pre-test was performed successfully on February 19, 2003. The follow-on tests also showed that the performance of the TL-VSL link was good. Therefore, the regular experiment has been discussed and undertaken from the middle of March 2003. The monthly experiment schedule was confirmed by the end of the previous month. The development, results, and future work about this link are illustrated in this report.

## **THE PRE-TEST OF TL-VSL**

The pre-test of the VSL-TL link was launched on February 19, 2003. According to the technical information of the allocated satellite transponders, TL must adopt the same polarization for both transmission and reception. Therefore, 2.4 m and 1.5 m dishes were used for transmission and reception at TL. The antenna size of VSL was 3 m. A SATRE modem and a MITREX modem were used at TL and at VSL respectively. The block diagram of the equipment connection is shown in Figure 1(a).

After the procedure to contact the PAS NOC by telephone for the Cross-Polarization Verification, the transmitted signal was changed from Clean Carrier to modulated carrier. VSL was able to lock on the signal from TL after changing the receive frequency by +5 kHz from nominal. A good C/N was obtained that enabled TWSTFT measurements. TL was able to lock on the signal from VSL after changing the receive frequency by +3.5 kHz from nominal. A C/N of about 42 dBHz was obtained, which was somewhat poor, but still enough to enable TWSTFT measurements. VSL also considered increasing its power to improve the performance.

Since both TL (SATRE modem) and VSL (MITREX modem) can successfully lock to each other. Thus, a TWSTFT link connecting through PAS-4 between TL and VSL has proven to be possible even with a very low elevation (about 4.9 degree) at VSL.

## **THE DEVELOPMENT OF TL-VSL LINK**

The similar experiment was repeated on March 06 to test the nominal TWSTFT experiment. In this session, another capacity of PAS-4 satellite was available; therefore, TL was able to perform the TWSTFT using a single 2.4 m dish with dual orthogonal polarizations for transmission and reception. The block diagram of the equipment connection is shown in Fig. 1(b). Table 1 shows a list of the equipment applied for this link. We succeeded again in this experiment with better performance than that of the pretest (e.g., a C/N value of 60.9 dBHz was obtained at TL). This satellite routing has been maintained for the TL-VSL link up to the present.

Since the middle of March 2003, the TWSTFT session between TL and VSL has proceeded once or twice a week. The monthly schedule was confirmed by the end of the previous month. Each individual

session, starting at 0800 UTC, lasted for 30 minutes. Data were then transferred by e-mail. Recently, both TL and VSL put the measurement files about this link on their anonymous FTP sites.

## DATA ANALYSIS

Figure 2 shows the results of UTC (TL) – UTC (VSL) obtained by using TWSTFT method. Since June 17 (MJD 52807), the RMS value of VSL's received data has improved because new Tx and Rx filters had been put in place. The received C/N at VSL has improved by more than 8 dBHz. The DRMS value of TWSTFT results in Figure 2 has obviously been ameliorated since MJD 52807.

The clock difference results (obtained by TWSTFT, GPS CV methods, and Circular-T data) of the TAI standard dates are calculated and illustrated in Figure 3. Because the TWSTFT data of TL-VSL link are unevenly spaced by intervals of 2, 5, or 7 days, they were linearly interpolated to give the data for the TAI standard dates with 5-day intervals. The time delay differences of the TWSTFT link have not been calibrated. Regarding the GPS CV results in Figure 3, the GPS data of VSL is obtained from the BIPM Web site. The data of TL were obtained from TL's multi-channel Topcon receiver, and the ionospheric effect was calibrated by the P1 and P2 codes. The moving-average method was used to smooth the TL-VSL GPS data. Figure 4 shows the difference of the TWSTFT and GPS results of the last 8 months. The RMS value is about 3.1 ns. The RMS value of the difference between TWSTFT and Circular T results is about 3.4 ns, as shown in Figure 5.

## CONCLUSIONS

The TWSTFT experiment performed between TL and VSL is herewith reported. The feasibility of TWSTFT comparison between Asia and Europe has been demonstrated by establishing the TL-VSL link. Although the elevation from VSL was only 4.9 degrees, the performance of this link is still acceptable. This should encourage other European laboratories to establish the Asian TWSTFT links.

For the present, the major inconvenience is that VSL has to adjust their earth station, which is currently applied for the regular USA link, before each session in order to match the pointing angle and the polarization for TL-VSL link. However, this inconvenience can easily be solved if an extra fixed antenna can be dedicated for the link to TL and maybe other Asian Pacific time laboratories. Besides, due to the policy of PAS, both TL and VSL have to phone the PAS NOC before and after each session. This will also cause the inconvenience in automating the operation procedure.

The TWSTFT results are compared with those of the GPS CV method in this report. The RMS value of the difference between these two methods is about 3.1 ns. The TWSTFT results can reflect the real-time difference between TL and VSL, since there is a good agreement in the time transfer curves obtained using the TWSTFT and GPS CV methods.

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- [3] J. Azoubib and W. Lewandowski, 20th BIPM TWSTFT Report, 20 March 2002.
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Table 1. TWSTFT equipment of TL-VSL link.

Equipment	TL	VSL
Antenna	Andrew 2.4 m dish	Andrew 3.0 m dish
Modem	SATRE (066)	MITREX / SATRE
Transceiver	CODAN 5900 (8W)	Miteq
External counter	HP5370B	SR620
Reference name	UTC (TL)	UTC (VSL)
Reference type	High performance Cs clock	High performance Cs clock

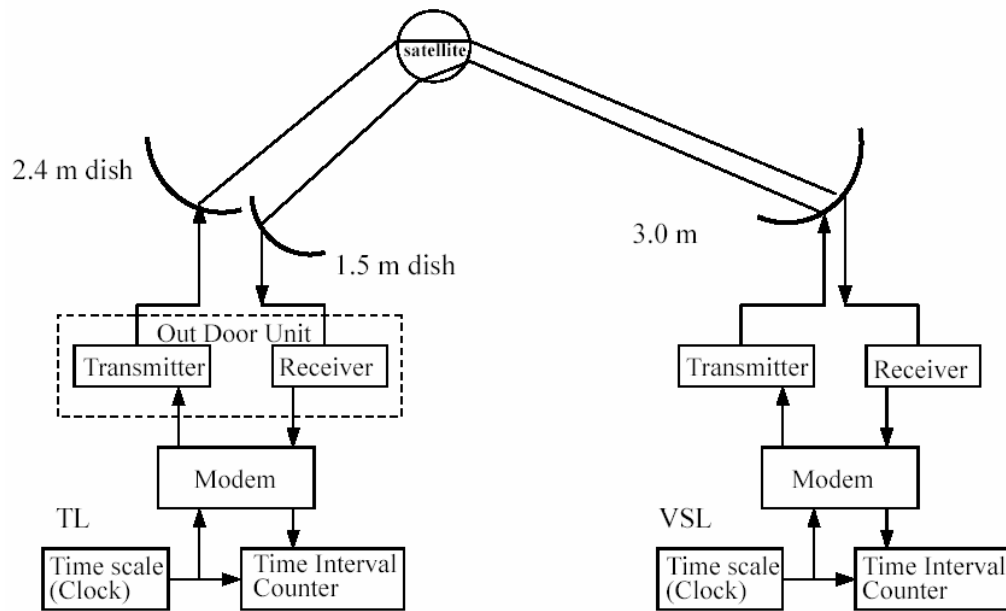


Figure 1(a). Block diagram of the equipment connection for the initial TL-VSL test.

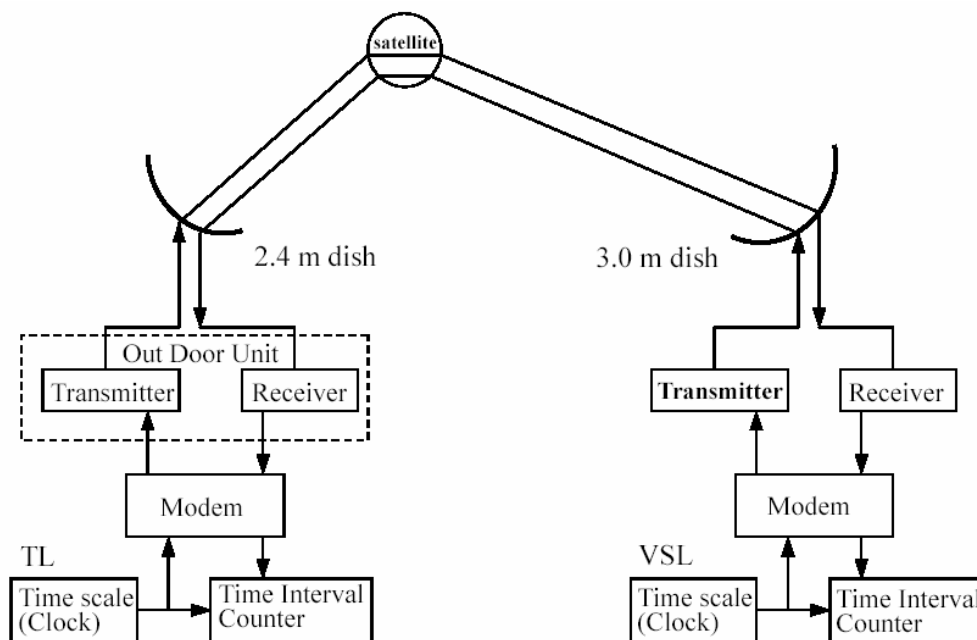


Figure 1(b). Block diagram of the equipment connection for the present TL-VSL link.

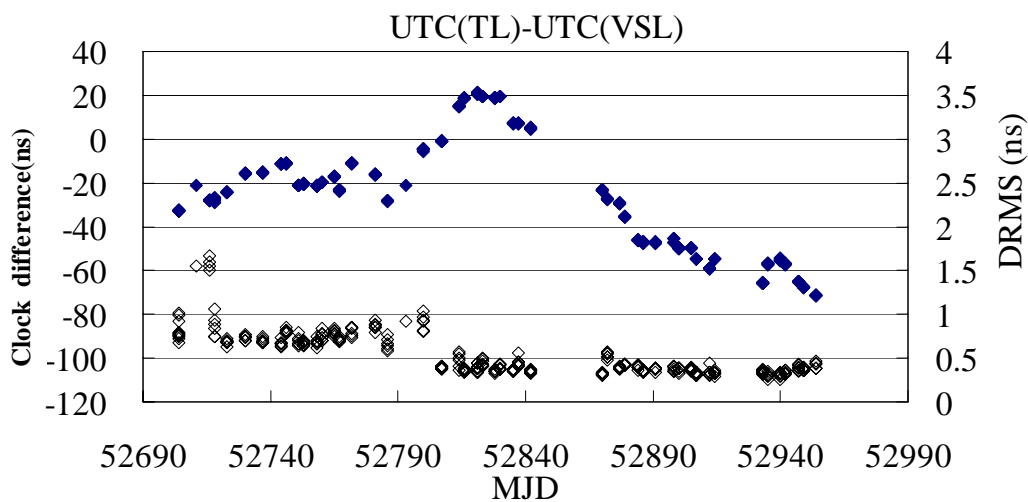


Figure 2. Results of  $[UTC(TL) - UTC(VSL)]$  by TWSTFT for the MJD period 52700 ~ 52960. The TWSTFT data have not been calibrated.

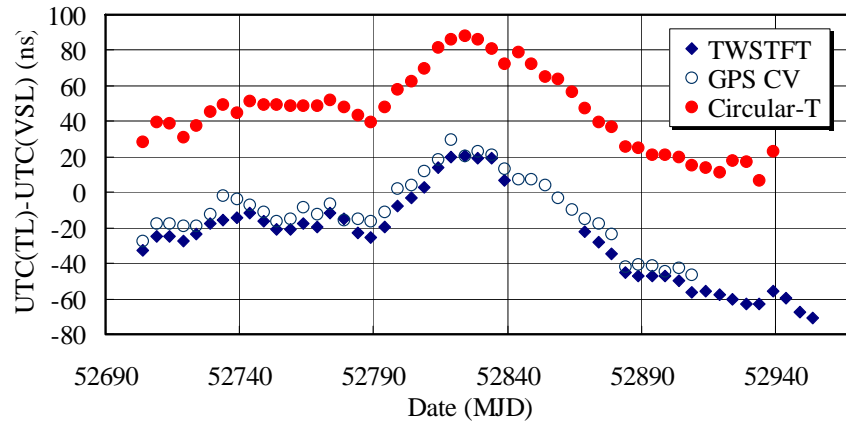


Figure 3. Clock difference results obtained by TWSTFT, GPS CV, and Circular-T for the TAI standard dates.

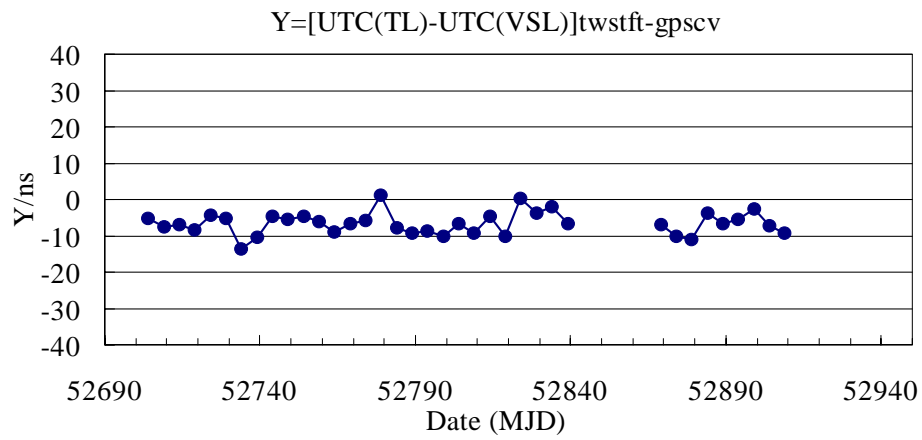


Figure 4. The RMS value of the difference between TWSTFT and GPS CV is about 3.1 ns.



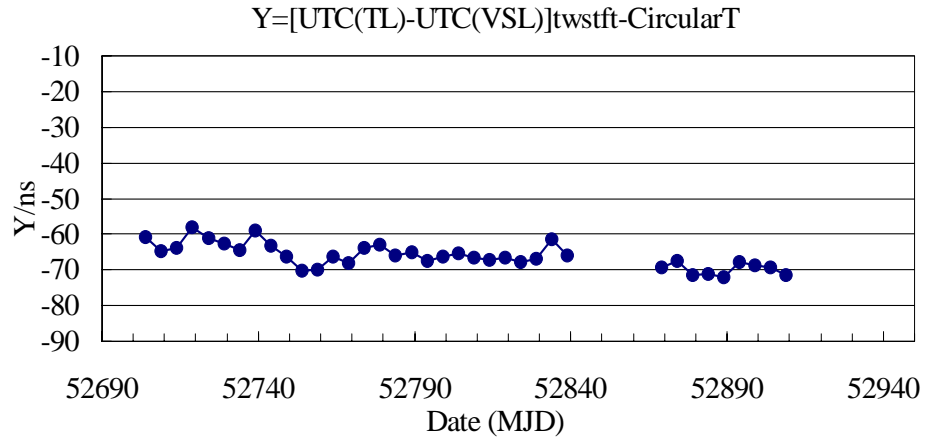


Figure 5. The RMS value of the difference between TWSTFT and Circular T is about 3.4 ns.

**QUESTIONS AND ANSWERS**

**JOHN DAVIS (National Physical Laboratory, UK):** Which of the laboratories in the Far East are able to see the satellite so they can take part in this work?

**SHINN-YAN LIN:** I guess the CRL in China can see the satellite. Certainly they have a very low look angle, but I can imagine.

**DAVIS:** Do you plan to continue running the experiment?

**LIN:** Yes, sure.

